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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G01W 1/14, G01F 3/00 | A1

(11) International Publication Number: WO 98/00736

(43) International Publication Date: 8 January 1998 (08.01.98)

(21) International Application Number: PCT/DK97/00285

(22) International Filing Date: 30 June 1997 (30.06.97)

(30) Priority Data:
0727/96 2 July 1996 (02.07.96) DK

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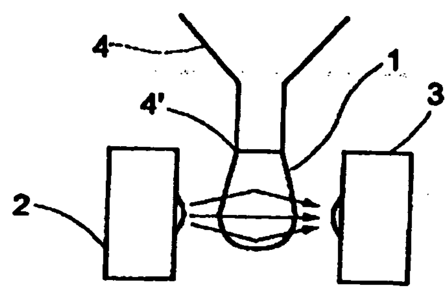
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
In English translation (filed in Danish).

(54) Title: OPTICAL FLOW METER

(57) Abstract

The invention relates to an optical fluid flow meter, preferably a rain gauge, performing reproducible measurements at a low current consumption. The invention benefits from the optical properties of rain drops, and is therefore not sensitive to the degree of pollution of the precipitation.



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OPTICAL FLOWMETER

Field of the invention

There are different methods for obtaining reliable and reproducible monitoring of precipitation. One example of these is given from US patent no. 4,520,667, in which a drop collector guides precipitation to a monitoring unit, as the drop collector guides the precipitation to electrodes, which short-circuit and deliver a monitoring pulse for each of the incoming drops. The number of registered drops is thereafter converted to an evaluation signal representing the precipitation in mm, inches or corresponding units.

This technique, however, has shown to be less reliable in geographical areas, where the precipitation is quite clean, as the drops not always are capable of short-circuiting the electrodes.

In US patent no. 4,314,484 a drop count apparatus utilising an optical registration of drops from a drop collector is known. Optical solutions, however, are problematic in many aspects, as these solutions are quite current consuming. This is in particular a problem, when using a battery as a power source. A further problem related to drop count apparatuses of the above kind is that they are sensitive to dirt, insects and the like when this is passing the registration units. This is in particular a problem when speaking about high accuracy measuring apparatuses.

It is the object of the invention to provide a method and an apparatus, which deals with these above mentioned drawbacks of the prior art..

The invention

According to the invention it is possible to obtain a reliable and reproducible measurement and minimal power consumption, as the convex shape of a drop focuses the light from the optical transmitter(s), whereby the intensity of light at the optical receiver(s) is increased, when the light is transmitted through the drops.

Thus, the measure object, e.g. each drop, works as a kind of optical amplifier, because of the reducing of the natural spreading of the light.

The increased intensity at the receiver provides a possibility to decrease the transmitter power at the transmitter, thus, reducing the necessary supply of power to the optical transmitter or transmitters. The method can advantageously be used in battery applications because of the fact, that the battery life time can be extended significantly. The method is therefore advantageous in transportable and relatively cheap hardware.

The method has important advantages over the use of various electrical short circuiting-electrodes as well as the method according to the invention introduces no inaccuracy or bias in dependence of diverging conductivity of the water resulted by purity or pollution.

Finally it should be mentioned, that the invention also provides the possibility for a relatively simple electrical dimensioning of the necessary hardware. This is for example the fact when choosing the necessary voltage level of the optical system, as this level under usual conditions desirable should be as low as possible.

A further advantageous embodiment of the invention can be achieved when the optical signals emitted by the transmitter(s) forms a pulse train, as it is thus possible to reduce the overall power or current consumption even more, and at the same time achieve a satisfactory and applicable level of light intensity by the receiver or the receivers.

It has moreover turned out, that the duty cycle of the pulse train surprisingly can be significantly reduced, as the invention can be utilised at relatively low voltage levels and a low current-/power- consumption. According to an advantageous embodiment, the duty cycle can be reduced to less than 1%, which in relation to battery applications provides a further significantly increasing of battery life time combined with a reproducible measurement. Within the scope of the invention, it is possible to adjust the period time and/or the "SET"-duration time. This adjusting may be static or dynamically as well.

In many relations it will also be attractive to let the measuring unit convert the counts of detected drops to a measure of rain over a certain interval of time, which subsequently may be shown at a monitoring unit e.g. a display.

According to a further advantageous embodiment the measuring unit may export the count measurement to a memory unit, as the measurement is moreover connected to a time of registration. Consequently the time of reading the unit becomes less critical, in the sense that all data can be collected and evaluated subsequently.

Another very important advantage of the invention is the fact that only a positive registration of a rain drop

pulse is possible, as the physical properties of the drop is necessary to obtain a registration. An impurity, an insect or the like would thus not trig an impulse, as no focusing and increased intensity at the receiver is provided. The invention is therefore particularly advantageous under conditions where there is a need for accurate measurements.

When, as stated in claim 1, a control unit initiates a registration of a passing drop in the optical path(s) when the electrical signal exceeds a predetermined threshold value, a method of measuring with improved precision is obtained.

A further aspect of the invention is, that the improved precision is obtained at the same time as a significantly decreased energy consumption. The decreased energy consumption is caused by the fact that the necessary supplied electrical power to the optical transmitting means can be reduced significantly, as the system in "idle-mode", i.e. no drop is detected, has no need for supplied energy causing a registration threshold value to be exceeded at the optical receiving means. Thus, as the invention generically takes advantage of the optical refraction properties of a drop. A drop in the optical path between the optical transmitting means and receiving means will act as a kind of optical amplifier, increasing the intensity of the received optical power at the optical receiving means causing the said threshold value to be exceeded. It is implicitly understood, that the invention as such from a technical point of view does not amplify the light guided to the optical receiving means, but rather perform a focusing of a part of the spread light from the optical transmitting means, thus causing a reduction of the spreading of the light when seen from the optical receiving means.

The understanding of the term fluid output is that the water from there can be guided to a container or directly out of the measuring apparatus.

When, as stated in claim 2, the control unit increments a drop count register when the electrical signal exceeds a predetermined threshold value an advantageous embodiment of the invention is obtained, as each drop is registered completely on the front edge or the rear edge of the drop.

When, as stated in claim 3, the optical signals emitted by the optical transmitting means are pulses, a particularly advantageous embodiment of the invention is obtained, as the electrical power consumption of the optical transmitting means can be further reduced.

When, as stated in claim 4, the means for calculation is arranged to initialise a registration of a passed drop in the measuring zone, when the electrical signal or a corresponding digital representation from the optical receiving means, exceeds a threshold stored in the means for calculation, a rain gauge having an improved accuracy is obtained

In addition to the advantages already mentioned in relation to the corresponding method of claim 1, it should be mentioned that the unique combination of a measurement of rain carried out in humid and not-encapsulated environments, a demand for battery supply, and thus a demand for low energy consumption, and a demand for an accurate and reproducible measurement is obtained according to the invention.

As the invention does not base the registration upon the shades created by the drops, but rather perform a positive detection of a drop, a high accuracy measurement is obtained.

By initiating a registration by exceeding a given threshold value, it should be understood that the initialisation itself not necessarily will cause a final and exact registration and subsequently the drop counter to be incremented. Thus it would be of great advantage to let the initialisation by the front edge of a drop be succeeded by a detection of the rear edge of the drop, whereby the drop can be regarded as a true measure and the drop counter can be incremented .

When, as stated in claim 5, the means for calculation increments a drop count register when the electrical signal or a corresponding digital representation from the optical receiving means exceeds a threshold value stored in the said means, an advantageous embodiment of the invention is obtained, which, in its generic form, is capable to register a drop on its front edge only without further detection and processing.

When, as stated in claim 6, the optical transmitting means 2 is arranged to emit pulse formed optical signals, a particular advantageous embodiment of the invention is obtained, as it has shown that a periodic activation of the optical transmitting means at a suitable dimensioning of the electrical and optical system can be implemented .

It should be understood that the pulses can have different kinds of shapes within the scope of the invention. Moreover it should be noted that the necessary number of light pulses depends on the kind of

application, as the number of pulses per time unit should be chosen so that it is ensured that no drops will be overlooked as a consequence that no pulse appeared when the drop passed the optical path between the optical transmitting and receiving means.

The duration of each pulse can likewise be adapted suitably from application to application. As an example the pulse can be maintained until the drop has passed the optical path, thus ensuring that the drop will be illuminated during the passage of the optical path. Thus, it will be possible unambiguously to register the rear edge of the drop, when the front edge of the drop has been detected.

Moreover the frequency and duration of the pulses can be adjusted. Another example of how a pulse can be "caught" in the drop counter can be effected when increasing the frequency of the pulses as a result of an exceeding of the threshold value. In some applications this way of operation can be advantageously if the rear edge of the drop has to be registered in a simple manner.

When, as stated in claim 7, the optical transmitting means is arranged to emit optical pulse formed signals having a constant period and duty cycle, said duty cycle being a measure for the optical emission time related to the total period time, a particular simple and easily applicable method according to the invention has been obtained, as the timer interrupts etc. can be performed by means of relatively simple and clear routines.

When, as stated in claim 8, the duty cycle of the pulse train approximately is 1% and the period time of the pulse is approximately 32 ms, a further advantageous embodiment according to the invention has been achieved,

which, when considering the electrical and mechanical properties of an application, can obtain a very current consumption combined with a very accurate registration.

When, as stated in claim 9, the rain gauge comprises a signal interface for transmission of data to an external unit connected to the means for calculation, said data being wholly or partly comprised of representations of the calculated drop flow or derived data thereof, a further advantageous embodiment according to the invention has been achieved, which can be applicable in e.g. measuring units of a more professional character, as the data in a certain measuring period, e.g. a week, can be transferred by a memory dump to an external calculation unit, e.g. a portable computer.

The above mentioned signal interface could for instance be a simple RS 232-interface.

If a periodic reading of the above mentioned type is implemented, it would typically be advantageous to store the data in connection with a read out time, thus ensuring that the precipitation can be related to specific period of time.

When, as stated in claim 10, the means for calculation converts the number of registered drops to a measure for the precipitation which subsequently is displayed on a display unit, an advantageous and user friendly application has been achieved.

When, as stated in claim 11, the distance between the optical transmitting means and the optical receiving means approximately is 10 mm at a drop size of approximately 5/100 ml, a further advantageous embodiment of the invention has been obtained, when dimensioned

under consideration to the degree of the focusing provided by a drop at the optical receiving means.

It should be understood, that this dimensioning moreover could be supplied with an adjustment of the means, which converts the rain into a drop flow of uniform drops. This adjustment could e.g. be done by adjustment of the diameter of the drop nozzle.

When, as stated in claim 12, the means for calculation is arranged to initialise a registration of a passed drop in the measuring zone, when the electrical signal or a corresponding digital representation from the optical receiving means exceeds a threshold stored in the means for calculation, a further advantageous embodiment of the invention has been obtained. The invention in its generic form can thus be utilised for many different types of fluid flow, volume or mass measurements, when the fluid is sufficiently transparent to guide light through the drop when the drop is passing the optical path and thereby causing an increased intensity at the optical receiving means.

Thus it is possible according to the invention to achieve very accurate estimates of weight and volume. Thus, the counting technique can be utilised for automatically regulated dosing.

Various types of software based algorithms can be utilised for obtaining the complete recognition of the drop, when the threshold has been exceeded. Whether these algorithms determines the progress of the drop by means of a recognition based system by detecting the rear edge of the drop, bases the recognition on the front edge of the drop or by means of other for the purpose suitable algorithms is to a certain degree a choice, which is

related to the specific system parameters, such as the shape of the drop or specifications for the chosen components.

When, as stated in claim 13, the control unit increments a drop count register when the electrical signal exceeds a predetermined threshold value, an advantageous embodiment of the invention has been obtained, which in its most simple form is capable of registering a drop on the front edge without further detection's or calculations.

When, as stated in claim 14, the optical signals emitted by the optical transmitting means are pulses, a particular advantageous embodiment of the invention has been obtained, as it has proved that a periodic activation of the optical transmitting means can be utilised without "overlooking" drops, when dimensioning the electrical an optical system suitably.

The figures

An example of an embodiment according to the invention will be described in the following referring to the figures, where

fig. 1 and 2 shows a figure of a preferred embodiment of the invention,

fig. 3 shows a more detailed timing chart of the trigger operation according the invention, and where

fig. 4 shows the electrical implementing of the optical system in an embodiment according to the invention.

The preferred embodiment

Fig. 1 shows the principles of an embodiment according to the invention. A drop collector 4 is arranged above an optical arrangement in such a way that a drop 1, when it is guided from the drop collector 4, is a part of the optical path between an optical transmitter 2 and an optical receiver 3 constituting the optical system in this example.

The drop collector 4 can be dimensioned mechanically in many different ways as long as the fluid flow is guided away from the drop collector shaped as drops.

The optical arrangement comprises in the considered example as a LED and a photo electrical receiver, or a usual optocoupler. The distance between the LED and the receiver is in the considered embodiment approximately 10 mm.

Fig.1 shows how a given amount of water is converted to a drop 1.

Fig. 2 shows the same arrangement, the drop 1 now released from the drop collector" and guided into the optical arrangement, hereby collecting or focusing the light from the LED by passage. This focusing increases the light intensity at the receiver 3, resulting in an exceeding over the threshold of the receiver 3. This results in an emitted pulse from the receiver 3 which will be registered and converted to an appropriate measuring unit, preferable mm or inches, in the measuring unit (not shown)

Fig. 3 shows another example of an introduced threshold value V_T, which may be used for detection of a passing drop. Thus, it can be seen that V_T is not exceeded when there is no drop, as the "idle" light intensity emitted

from the optical emitter is not sufficient to exceed the threshold value V_T. However, the appearance of the drop causes the light intensity to be focused at the optical receiver in such a way, that it exceeds to a level above the threshold value.

It must be emphasised that the above mentioned course is only discussed in a simplified form, and as such does not limit the scope of the invention. The curve form can be significantly different from the above mentioned depending of the transmitter/receiver location.

Fig. 3 shows a timing chart for the overall system, when it is trigged by a down falling drop.

The periods A to F show the timing between the electrical signals, and the physical measurement of a drop collected by and guided away from a drop collector.

In the timing chart the simultaneous operation of transmitter LED, showing when the light/the transmitting diode is turned on, SET, showing the registration history and being used for the drop counting when inverting the reference level, and IN, showing the level of the received light in the form of a corresponding electrical signal.

According an embodiment of the invention the period time is 32.35 ms and the time when LED is high is 0.35 ms giving a duty cycle of approximately 1 %.

SET will be set high of the system, when LED is set high, and will be maintained high, if the drop has shaded the receiver (upper trigger threshold exceeded on IN). SET will be maintained high in the following measuring periods until the drop focuses enough light that IN reaches the low threshold voltage.

The electrical components coupled to IN may be dimensioned suitably such that the trigger or threshold on IN corresponds to the logical threshold value of the input gate. In other applications an A/D gate may be suitably used.

In the period A there is no drop in the drop collector nor in measuring zone. LED is going high in 0.35 ms and light is transmitted from the transmitting diode. Moreover SET is set high, while IN, being an input value, only rises to a level below V_{TH}. As the threshold value V_{TH} is not reached when LED is high, SET and IN as well will fall to 0V when LED goes low. SET falls instantly, while a certain fall time for IN will appear due to the electrical construction.

In the period B a drop from the drop collector is being led into the measuring zone. The drop will provide a certain amount of shadow, but not enough to exceed V_{TH}.

In the period C the drop has passed into the measuring zone and now shades so that V_{TH} is exceeded. This event is registered internally in the microprocessor and SET is maintained high at the end of the period.

In the period D the drop has now passed enough into the measuring zone so that it gradually guides light to the receiver in such a way that the intensity increases.

In the period E the drop has now passed enough down into the measuring zone to focus all the light in the receiver and IN reaches a low trigger voltage - and a drop is registered.

The time of each measuring period should be chosen carefully in such a way that no drop would be overlooked. This dimensioning depends in technical respect of the physical properties of the drop flow and depends in economical respect of the best possible minimising of current consumption.

Thus, the circuit shown at fig. 3 utilises a combined shading and focusing recognition, as a shade and a focusing in practice can be said to act in opposite phase in the shown example.

It should be noted that the actual positive recognition of the drop in this example is carried out at the rear edge of the drop.

Software routines can likewise be supplemented with internal filters, as it e.g. can be advisable to use an extra count register, which implemented in software will secure that the system not registers a pulse the next five readings after registering of a drop or a drop-like pulse. This corresponds mechanically to a dimensioning of the system so that the drop collector and nozzle provides a maximum drop flow of approximately five per second.

Moreover, other software adaptations can be utilised in specific applications.

An example of a further routine, could be to add a requirement for two positive registrations on the same drop before it is accepted as a real drop and the drop count register is incremented.

Fig. 4 shows an example of how the optical system (the optocoupler) is wired and connected to a microprocessor.

A microprocessor 10 comprising an output 20, OUT SET, is electrically connected to a transmitter of an optocoupler 13 via a adapter resistor 15 and a grounded 17 capacitor 14. Moreover, the transmitter of the optocoupler is connected to ground 17.

The receiver of the optocoupler 13 is paralleled with a capacitor 12 to ground 17. Two resistors 11 and 16 connects the parallel coupling to respectively an output 21, OUT SET, and an input 22, IN, on the microprocessor 10.

Thus, at normal function a drop, when arriving in the optical path in the optocoupler 13, in the beginning will result in a shading of the receiver 13, such that the photo diode in the optocoupler gradually will be interrupted. As OUT SET 21 will be set high at every OUT LED impulse from the output 20, V_{IN} will be charged to a value being higher than V_{TH} 32 on fig. 3, by appropriate dimensioning of the resistors 16 and 11 and the belonging capacitor 12. As consequence of this a software routine will set OUT SET 21 high.

OUT SET 21 is subsequently high until the drop in the optocoupler 13 focuses the light so much, that the receiver of the optocoupler begins to conduct and the

capacitor 12 is short circuited to ground 17. This procedure appears from the third period C of fig. 3.

Subsequently the drop counter will be incremented.

The capacitor 12 may thus be dimensioned when bearing in mind, that the resistor in the photo diode of the optocoupler within a period shall be able to pull the capacitor 12 low.

According to the preferred embodiment an increased quality of measurement and a low current consumption is achieved. Thus, it is possible to obtain a battery life time of two years or more in a standard application when using a battery of 1.5V (900mAh), thus illustrating the advantages gained by using the drop flow itself to focus the light on the receiver, and thereby decreasing the necessary transmitting intensity. The low current consumption is further decreased as the measuring time is only part-time.

The structure of the shown activation of the LED has form of a pulse train having a constant period and a constant duration of the activation. It should nevertheless be noted that the shape of activation is not crucial. It is therefore within the scope of the invention possible to change the period or the time duration of activation dynamically as a function of currently applicable criteria's, as e.g. the state of the system can form the basis of the mentioned changes. As an example the system could be adapted to transmit bursts of pulse trains, if no drop flow has been detected over a given period of time and then return to a constant pulse train at the first indication of a fluid flow.

C L A I M S

1. A method for optical measuring of precipitation, in which the precipitation is collected by means for collection of precipitation and from there guided in the shape of drops to a fluid output via a measuring zone,

each drop in the measuring zone passing at least one optical path between optical transmitting means and optical receiving means,

each optical receiving means outputting an electrical signal in dependence of the intensity of the light signal received at the optical receiving means,

characterised in that a control unit (10) initiates a registration of a passing drop in the optical path(s) when the electrical signal exceeds a predetermined threshold value.

2. A method according to claim 1, characterised in that the control unit (10) increments a drop count register when the electrical signal exceeds a predetermined threshold value.

3. A method according to claim 1 or 2, characterised in that the optical signals emitted by the optical transmitting means are pulses.

4. An electronic optical rain gauge comprising means for collecting rain water and coupled means for converting the collected rainwater to drops of a given predetermined dimension, said drops being guided from the means for converting the collected rainwater in at least well defined drop path,

at least one connected measuring zone comprising optical transmitting means and optical receiving means defining at least one mutual optical path from the optical transmitting means to the optical receiving means,

said optical transmitting means being arranged for emission of light in dependence of an electrical control signal,

said optical receiving means being arranged for emission of an electrical signal in dependence of the light received at the optical receiving means,

said measuring zone being arranged such that at least one of the said drop paths passed at least one of the mutual optical paths,

said optical receiving means being electrically connected to means for calculation,

characterised in that

the means for calculation is arranged to initialise a registration of a passed drop in the measuring zone, when the electrical signal or a corresponding digital representation from the optical receiving means exceeds a threshold stored in the means for calculation.

5. Electronic rain gauge according to claim 4, characterised in that the means for calculation (10) increments a drop count register when the electrical signal or a corresponding digital representation from the optical receiving means exceeds a threshold value stored in the said means.

6. Electronic rain gauge according to claim 4 or 5, characterised in that the optical transmitting means (2) is arranged to emit pulse formed optical signals.

7. Electronic rain gauge according to claims 4-6, characterised in that the optical transmitting means (2) is arranged to emit optical pulse formed signals having a constant period and duty cycle, said duty cycle being a measure for the optical emission time related to the total period time.

8. Electronic rain gauge according to claims 4-7, characterised in that the duty cycle of the pulse train approximately is 1%, and that period time of the pulse is approximately 32 ms.

9. Electronic rain gauge according to the claims 4-8, characterised in that the rain gauge comprises a signal interface for transmission of data to an external unit connected to the means for calculation, said data being wholly or partly comprised of representations of the calculated drop flow or derived data thereof.

10. Electronic rain gauge according to the claims 4-9, characterised in that the means for calculation converts the number of registered drops to a measure for the precipitation which subsequently are displayed on a display unit.

11. Electronic rain gauge according to the claims 4-10, characterised in that the distance between the optical transmitting means and the optical receiving means approximately is are 10 mm at a drop size of approximately 5/100 ml.

12. Electronic flow meter comprising means for converting collected transparent fluid to drops of a given predetermined dimension, said drops being guided from the means for converting in at least well defined drop path,

at least one connected measuring zone comprising optical transmitting means and optical receiving means defining at least one mutual optical path from the optical transmitting means to the optical receiving means,

said optical transmitting means being arranged for emission of light in dependence of a electrical control signal,

said optical receiving means being arranged for emission of an electrical signal in dependence of the light received at the optical receiving means,

said measuring zone being arranged such that at least one of the said drop paths passed at least one of the mutual optical paths,

said receiving means being electrically coupled to means for calculation,

characterised in that

means for calculation is arranged to initialise a registration of a passed drop in the measuring zone, when the electrical signal or a corresponding digital representation from the optical receiving means exceeds a threshold stored in the means for calculation.

13. Electronic flow meter according to claim 12, characterised in that the control unit (10) increments a

drop count register when the electrical signal exceeds a predetermined threshold value.

14. A method according to claim 12 or 13, characterised in that the optical signals emitted by the optical transmitting means are pulses.

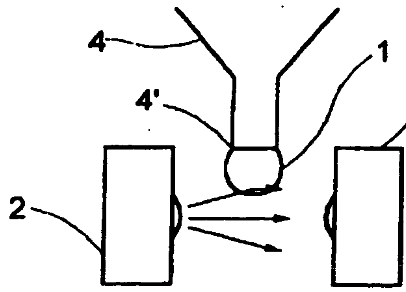

FIG.1

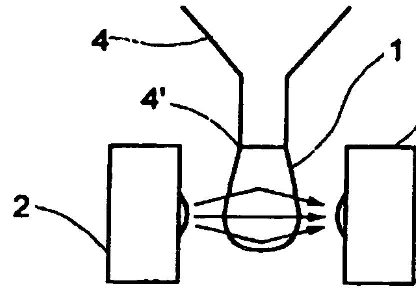

FIG.2

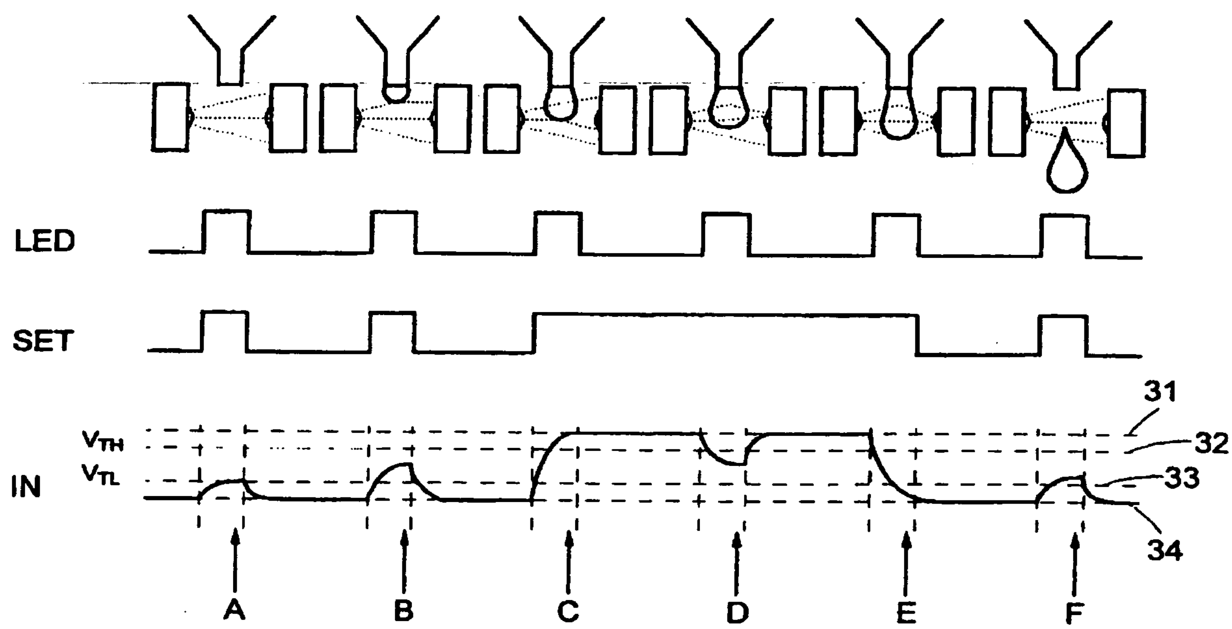

FIG.3

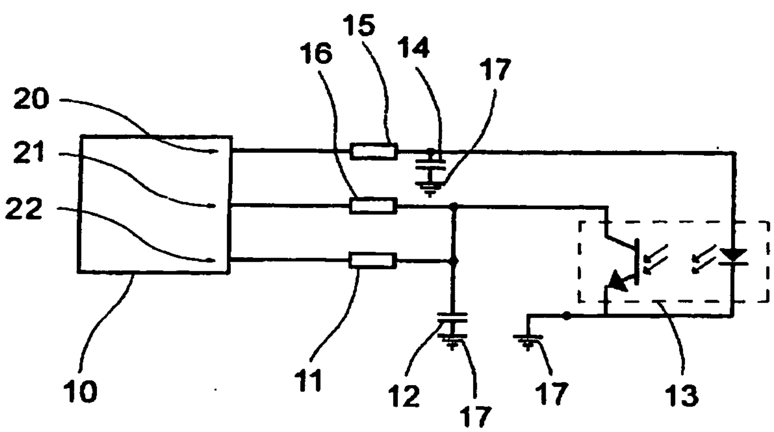

FIG.4

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 97/00285

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G01W 1/14, G01F 3/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: A61M, G01F, G01N, G01P, G01W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	FR 2293718 A1 (DONNADIEU GEORGES ET AL.), 2 July 1976 (02.07.76), see the whole document	1-3,4-11
X		12-14
	--	
Y	US 4314484 A (R.J. BOWMAN), 9 February 1982 (09.02.82), column 6, line 63 - column 8, line 26, figures 1,4	1-3,4-11
X		12-14
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
16 October 1997	20 -10- 1997
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Lars Jakobsson Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 97/00285

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